Chapter 1:
The Economic Potential of an Advanced Biofuels Sector in Massachusetts

As a new and growing industry, biofuels could add to the Commonwealth's economic engine, starting and attracting companies, creating and retaining jobs, and growing the Massachusetts clean energy sector. Furthermore, biofuels offer alternatives to our current reliance on petroleum-based fuel sources—a dependency that sends economic benefits out of state, to foreign countries or other parts of the U.S.

This chapter is designed to provide a preliminary assessment of the potential economic benefits to Massachusetts of an advanced biofuels sector.* This discussion focuses solely on advanced biofuels—defined as renewable fuel that reduces net lifecycle greenhouse gas emissions by at least 50%. First-generation biofuels, such as corn-based ethanol and biodiesel produced from oils and fats, have a role to play in the short run. But it is advanced biofuels—which have not yet reached commercial viability—that hold the most promise for clean, reliable, renewable energy for the future, and for economic development in the Commonwealth.

Economic benefits associated with biofuels are expected to come from three main sources: technology development, use of biomass feedstock from in-state sources, and construction and operation of processing facilities. Technology development would leverage Massachusetts's strengths in technical know-how, entrepreneurship, and venture capital to create new companies and bring new products to national and international markets. Use of local cellulosic materials would have particular value for the local economy, retaining jobs in forestry and agricultural industries that might otherwise be lost. Production of advanced biofuels using local cellulosic feedstock also has high economic value because Massachusetts has no fossil fuel resources of its own. Consequently, residents and businesses in the Commonwealth spend billions of dollars a year to buy petroleum fuels from other states and countries—a large drain on our economy. In-state feedstocks could replace on the order of 6% of our petroleum use, and substantially more could come from other Northeastern states (see Chapter 3)—a significant amount, but still a small fraction of total consumption.

To the degree that biofuels are used by consumers in Massachusetts, but the feedstocks are grown and processed into fuels in other states, our spending on fuel imported from outside the state would not be reduced. There are, however, economic and political gains to the U.S. as a whole from reducing petroleum imports from other countries.

Economic gains to Massachusetts come first from the "direct" economic activity in companies engaged in research and development, in providing biomass feedstocks,

* The analysis in this chapter was conducted by Navigant Consulting, Inc. and Task Force staff, looking at feedstock potential within the state and at potential development of the R&D sector. Final calculations of direct impacts were made by Task Force staff, and converted to total impacts by applying estimates of economic multipliers for Massachusetts. The multipliers are based on a high-level review of multipliers for economic sectors relevant to biofuels, generated by the IMPLAN model and provided by Economic Development Research Group. See Appendix A for a more complete treatment of methodologies used in Chapter 1.

in operating processing facilities, and in constructing such facilities. There are also secondary "multiplier" (also known as indirect and induced) gains as biofuel companies buy products and services from other firms in Massachusetts, and as employees spend their incomes within the state.

Cellulosic fuels are not expected to reach competitive levels in the marketplace for at least five years, and after that their production will develop over time. The analysis below assumes that by 2025 the industry will have grown to the point where Massachusetts's in-state resources of cellulosic feedstock are used on a large scale for processing into biofuels at in-state facilities.

We estimate permanent annual economic potential—from technology development, feedstock provision, and facility operation —at 1,000 to 4,000 jobs, and $280 million to $1 billion in annual gross state product by 2025. With multiplier effects for indirect impacts added in (as spending re-circulates throughout the state's economy), the potential gains rise to 2,500 to 9,800 jobs and $550 million to $2 billion in economic activity.

Table 1.1: Summary of Economic Opportunities from Advanced Biofuels (annual as of 2025 except for construction)			
	Low	Middle	High
Direct impacts			
State product ($ millions)			
Permanent	$280	$640	$1,000
Construction (temporary)	$20	$70	$110
Employment (number of jobs)			
Permanent	1,000	2,500	4,000
Temporary construction	150	460	760
Total impacts including multiplier			
State product ($ millions)			
Permanent	$550	$1,270	$1,990
Construction (temporary)	$50	$160	$260
Employment (number of jobs)			
Permanent	2,500	6,200	9,800
Construction (temporary)	350	1,050	1,750

This overall potential can be broken down into its constituent parts. One major part, advanced biofuels technology development, can serve national and global markets. We estimate that technology development could yield 630 to 2,000 direct jobs, and $125 million to $400 million in gross state product. Including indirect and induced impacts, the total gains would be 1,600 to 5,300 jobs and $270 million to $850 million.

The second major economic potential is from biofuel production in Massachusetts, but it is unclear to what extent in-state biomass will be used for biofuels consumed here and how much processing will be done here. Assuming varying levels of in-state industry development, we estimate direct, permanent gains to the state's economy of 380 to 2,000 jobs and $150 million to $600 million in gross state product. Including multiplier effects, the total gains would be 860 to 4,600 jobs and $280 million to $1.14 billion.

In addition, there will be jobs and economic gains from construction during those years when processing and other facilities are being built. If these were spread evenly over a 15-year period, for example from 2010 through 2025, the average direct benefits would be 150 to 760 jobs and $20 million to $110 million. Including indirect/induced impacts, the state would realize 350 to 1,750 jobs and $50 million to $260 million.

Additional economic benefits may include cost savings to consumers (if biofuels are less expensive than fossil fuels), increased state tax revenues, lower health care costs from cleaner air, and reduced energy price volatility. These have not been quantified in this preliminary assessment, but should be part of a more comprehensive analysis of economic potential.

The Advanced Biofuels Sector: Current Status and Future Potential

The recently published "Massachusetts Clean Energy Industry Census"[1] reports that "Clean Energy" is the fastest growing sector of the state's economy, already supporting 14,400 jobs and 556 companies across the Commonwealth. Renewable energy is a key component of this cluster of economic activity, with the report highlighting that "renewable energy companies are the youngest and fastest growing firms."

Overall, the size of the state's existing biofuels sector is small. There is some "downstream" activity as petroleum wholesalers and retailers blend conventional biofuels into refined petroleum products (often to comply with federal and state regulations). On the other hand, there are minimal "upstream" activities, such as biomass cultivation and collection. In terms of technology development, a surge of interest in the sector has occurred recently, with five to eight early-stage technology companies emerging in Massachusetts in the past few years alone.[2] This suggests that the state is well-positioned to capture future growth in this area.

As discussed in the appendix to this chapter, for purposes of the economic impact analysis it is necessary to distinguish between the operational deployment and technology development value chains. It should be noted that this distinction reflects, to a certain degree, a geographic divide—with the more rural areas of western Massachusetts expected to accrue a larger share of economic benefits on the operational side of the advanced biofuels sector, and the state's eastern urban centers reaping more of the technology development benefits.

Operational Deployment

Massachusetts has only modest agriculture and forestry sectors and is not considered a major area of biomass feedstock supply. Other New England states—primarily Maine with its large forest products sector and forest biomass resource base—have more substantial potential. Nevertheless, given the promise of biofuel technologies under development that will be able to convert a broad range of feedstocks (including agricultural and forestry residues, industrial and urban wastes), the potential displacement of petroleum imports with biofuels produced from local feedstocks can result in important economic benefits for Massachusetts.

First-generation biofuels, such as corn-based ethanol and biodiesel produced from oils and fats, have a role to play in the short run. But it is advanced biofuels—which have not yet reached commercial viability—that hold the most promise for clean, reliable, renewable energy for the future, and for economic development in the Commonwealth.

To characterize the range of potential feedstock supplies from within the state for advanced biofuels production by the year 2025,[3] three distinct scenarios (Low, Medium and High) were developed based on a review of publicly available literature.[4] It is important to emphasize that the potential in-state production of conventional biofuels was not considered (although this is discussed in Chapter 3).[5] The next 20 years will likely see the emergence of a number of conventional biofuel operations, predicated mostly on feedstock imported from out-of-state. These operations will generate some economic benefits despite the more limited value created for the local economy when feedstock is imported.

Table 1.2: Feedstock Availability and Biofuels Production Potential in Massachusetts									
2025 Scenario	Available Biomass Feedstock (1,000s Dry Tons / Yr)							Biofuels (GGE[1])	
	Forest Residues	Mill Residues	Dedicated Energy Crops	Urban Wood Wastes[3]	Organics from Municipal Solid Waste[4]		Total	Average Yields (GGE / ton)	Production (MGPY[2])
					Disposed[5]	Recycled[6]			
Low	100	100	150	500	700	100	1,650	60	100
Medium	200	150	250	800	900	200	2,500	80	200
High	350	200	600	1,000	1,200	400	3,750	100	380
1: Gallons of Gasoline Equivalent									
2: Million Gallons of Gasoline Equivalent Per Year									
3: Includes yard wastes (recycled and disposed) + biomass fraction of C&D waste (recycled and disposed)									
4: Organics Fraction of MSW: includes paper, food waste, food scraps, other. Excludes all yard waste & C&D									
5: Landfilled & Incinerated									
6: Recycled, Composted and otherwise diverted - Lower figures reflect challenges of diverting from other uses									

We should be harnessing our research abilities and entrepreneurial spirit to develop and commercialize the next wave of renewable biofuels—sources of energy that (1) create local jobs; (2) increase energy independence; (3) promote fuel diversity; and (4) significantly reduce greenhouse gas emissions.

—Environment Northeast, testimony to the Massachusetts Advanced Biofuels Task Force, January 17, 2008

Table 1.2 summarizes the results of this analysis, as well as the estimated breakdown between the main feedstock categories for each scenario.

Assuming the medium scenario in Table 1.1, advanced biofuels production in 2025 would total 200 million gallons per year, displacing over 6% of 2006 gasoline consumption in Massachusetts. The size of individual facilities will be the result of trade-offs between economies of scale in construction and operations and diseconomies of scale in feedstock procurement. Based on current forecasts, advanced biofuels plant sizes will range between 10 million and 60 million gallons of gasoline equivalent per year.

Technology Development

Technological innovation is an area of strength for the Massachusetts economy due to the presence of superior academic institutions and technology clusters in the biotech and defense sectors. As a consequence, the state is well-suited to attract economic activities in this area, as evidenced by the increase of early stage companies that have surfaced over the past few years and the academic partnerships established to attract private and public R&D funds for advanced biofuels development.

Attempting to estimate the size of an advanced biofuels R&D sector and its impacts on the Massachusetts economy in 20 years is difficult given the uncertainties facing this emerging industry. Unlike feedstocks, intellectual property—the product of technological innovation—is readily transferable and can create significant value for the state. Technology development activities are, therefore, not constrained by local circumstances, but can serve national and global markets.

The Advanced Biofuels Sector: Economic Impacts

Operational Deployment

Price projections from the U.S. Department of Energy's Energy Information Administration were used to estimate the total economic value generated by advanced biofuels operations in 2025 for the three scenarios described in Table 1.1.[6] Other assumptions are outlined in the appendix.

Tables 1.3a and 1.3b summarize the results of the analysis: the operational deployment of advanced biofuels has the potential to generate an incremental direct economic impact on the Massachusetts economy in the year 2025 estimated at approximately $150 million to $600 million annually (for the Low and High case scenarios, respectively). A high-level review of economic development multipliers for the Massachusetts economy suggests that

Table 1.3a: Annual Direct Economic Output Gains in 2025 – $ millions				
	Low	Medium	High	Comment
Construction - Average over 15 Years	$23	$68	$114	Temporary
Operations	$150	$375	$600	Permanent
Technology Development	$125	$263	$400	Permanent
Total $ millions	**$298**	**$706**	**$1,114**	
***of which* Permanent Only ($ millions)**	**$275**	**$638**	**$1,000**	

Table 1.3b: Annual Total Economic Output Gains Including Multiplier Effect in 2025 – $ millions				
	Low	Medium	High	Comment
Construction - Average over 15 Years	$52	$157	$262	Temporary
Operations	$285	$713	$1,140	Permanent
Technology Development	$266	$558	$850	Permanent
Total ($ millions)	**$602**	**$1,427**	**$2,252**	
***of which* Permanent Only ($ millions)**	**$551**	**$1,270**	**$1,990**	

for every $1 million of direct economic output that is created, $0.9 million of indirect and induced output is also generated.[7] Therefore, if $600 million a year of direct output is created, the true impact on economic activity is approximately $1.14 billion annually. The results also highlight that the lion's share of this economic benefit occurs in the following segments of the value chain:

- "Feedstock Production and Collection", i.e. the agricultural, forest products and waste management sector of the local economy; and
- "Biofuels Production", i.e. the industrial processing sector.

In addition to direct output, the analysis examined economic impacts from operational deployment in terms of direct jobs created. Key assumptions are outlined in the appendix. Tables 1.4a and 1.4b summarize the results of the analysis: the operational deployment of advanced biofuels is estimated to generate between 375 and 2,000 permanent direct jobs and between 150 and 760 temporary construction jobs, with salaries ranging from $30,000 to $75,000. The multiplier for indirect and induced employment effects is

Table 1.4a: Direct Jobs Created – Annual in 2025 (except construction)				
	Low	Medium	High	Comment
Construction - Job Years Total	2,250	6,825	11,400	Temporary
Construction - Average over 15 Years	150	455	760	Temporary
Operations	375	1,188	2,000	Permanent
Technology Development	625	1,313	2,000	Permanent
Total jobs	**1,150**	**2,955**	**4,760**	
***of which* Permanent jobs only**	**1,000**	**2,500**	**4,000**	

Table 1.4b: Total Jobs Created Including Multiplier – Annual in 2025 (except construction)				
	Low	Medium	High	Comment
Construction - Average over 15 Years	345	1,047	1,748	Temporary
Operations	863	2,731	4,600	Permanent
Technology Development	1,641	3,445	5,250	Permanent
Total jobs including temporary	**2,848**	**7,223**	**11,598**	
***of which* Permanent jobs only**	**2,503**	**6,177**	**9,850**	

1.3—meaning that for every direct job created, 1.3 additional indirect and induced jobs are expected to result.

Technology Development

The economic impact of early stage technology development is generally measured in terms of R&D investment capital provided through public funding and private investors. Over the long-term, technologies are expected to be commercialized, generating a return on those investments. While different firms use different business models to reap the benefit of technology innovation, the pure value of technology development can be estimated by the sale of intellectual property through royalty payments. For this analysis, the economic impacts of technology development are measured in terms of the stream of potential royalty revenues generated from commercialized advanced biofuels technologies (i.e. the value of goods and services). The analysis assumes that by the end of this period (2025), the biofuels industry will have matured substantially from its current state.

> UMass has formed an interdisciplinary team of forward-looking researchers whose work is aimed at the development of cost-effective technologies for producing ethanol, alternative fuels, and other value-added materials from biomass…. This work has already led to the creation of one commercial spin-off from UMass–Amherst: SunEthanol, a biofuels company that is developing a cellulosic ethanol production technology.
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> *—A Report of the UMass Clean Energy Working Group, February 2008*

Based on assumptions detailed in the appendix, the incremental direct output generated in the local economy is estimated in the range of approximately $125 million to $400 million per year. This value could increase significantly if Massachusetts-based companies participate not only by selling technology but also, for example, by providing engineering and operation and maintenance services to plant owners, or owning and operating facilities globally. In addition, the technology platforms now under development for biofuels will provide valuable breakthroughs for large-scale production of bio-based chemicals and products to replace those derived from fossil fuels.[8] The value of the intellectual property created for these applications will generate additional benefits for the state's economy that have not been estimated here.

Finally, potential direct job creation from advanced biofuels technology development is estimated at 625 to 2,000 jobs per year. Moreover, job quality as measured in terms of average expected salary is higher in this area of activity than for jobs related to operational deployment.[9]

This economic impact analysis does not discuss or consider the large risks and challenges facing the advanced biofuels industry. Rather, it assumes that the core risks and challenges are successfully addressed, allowing advanced biofuels to become a viable and integral part of the energy sector. Substantial technological performance improvements and scale-up, as well as infrastructure barriers, lie ahead. The economic viability of advanced biofuels still needs to be proven and the true extent of the environmental benefits and downsides require additional analysis, as discussed in subsequent chapters of this report.

Methodological Appendix

See Appendix A to this report for further information on the methodology used in this chapter.

Chapter 1 Endnotes

1. Massachusetts Clean Energy Industry Census, Mass. Technology Collaborative, August 2007, http://www.mtpc.org/Clean-Energy-Census-Report-2007.pdf
2. Companies include: Verenium, Mascoma, SunEthanol, Agrivida, BioEnergy International, GreenFuel Technologies. All have received substantial venture funding.
3. The choice of the year 2025 is arbitrary, but reflects the need to look at a period in time that is far enough in the future for the industry to have matured substantially from its current stage in terms of technology, markets, and infrastructure, in order to achieve its economic development potential.
4. List of literature reviewed:
    - "A Geographic Perspective on the Current Biomass Resource Availability in the United States", A. Milbrandt. NREL, December 2005.
    - "Estimated Annual Cumulative Biomass Resources Available by State and Price", ORNL. March 1999.
    - "The Woody Biomass Supply in Massachusetts: A Literature Based Estimate", Northeast Regional Biomass program (NRBP). May 2002.
    - "U.S. Biofuels Production Potential" based on spreadsheet developed by the National Biomass Partnership. August 2007.
    - "25% Renewable Energy for the United States by 2025: Agricultural and Economic Impacts", 25x25 Coalition. November 2006.
    - "Waste Reduction Program Assessment and Analysis for Massachusetts", February 2003, MA DEP http://www.mass.gov/dep/recycle/priorities/tellrep.pdf
    - "2006 Solid Waste Data Update on the Beyond 2000 Solid Waste Master Plan", February 2008, MA DEP http://www.mass.gov/dep/recycle/priorities/06swdata.doc
    - "Identification, Characterization, and Mapping of Food Waste and Food Waste Generators in Massachusetts. Final Report" September 19, 2002. Prepared for MA DEP. Bureau of Waste prevention.
5. The production of biodiesel or heating oil substitutes from used vegetable oil and animal fat (commercially known as Yellow Grease, YG, and Trap or Brown Grease) is not considered in this economic impact analysis for two reasons: 1) The feedstock potential in the state for this application is limited; and 2) Used vegetable oils recycled mainly from commercial food establishments in the state are already upgraded to a valuable commodity such as YG by the local rendering industry (#2 YG is traded at about 50% of the value of virgin vegetable oil, currently at about 20 cents/pound); economic value is already created in this operation and the economic impact to the state's economy of further upgrading YG to biodiesel (or using it directly as fuel) is limited. This choice, however, is not meant to diminish the societal value of this application or the potential benefit to certain sectors of the local economy from further enhancing the value of the resource. Similar considerations may apply for the recycled fraction of solid biomass waste that we considered in Table 1.2.
6. High Price Case Projections AEO 2007. http://www.eia.doe.gov/oiaf/archive/aeo07/pdf/aeohptab_12.pdf. The analysis uses the projected price for gasoline and discounted for taxes,

retail distribution costs and margins to obtain a wholesale price applicable to advanced biofuels—value used is $2.70/GGE.

7. Using IMPLAN and considering the following economic sectors: grain farming, logging, forest products and timber, corn wet milling, agriculture and forestry support activities, sawmills, pulp mills, paper and paperboard mills, paperboard container manufacturing, water transportation, truck transportation.

8. Demand for degradable plastics (just one of the potential commercial applications of the technology platforms) is expected to rise from 100 million lbs. in 2000 to 500 million lbs. in 2010.

9. Anecdotally, the average salary for jobs in biotechnology in Massachusetts (a similar job profile to jobs expected to be created in advanced biofuels technology) is about $100,000 per year.